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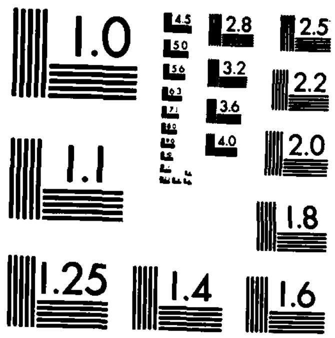

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The downstream effects of peaking hydropower generation at Lake Hartwell Georgia-South Carolina, on the diel prey selection and feeding of four species of fish--silver redhorse (*Moxostoma anisurum*), redbreast sunfish (*Lepomis auritus*), green sunfish (*L. cyanellus*), and bluegill (*L. macrochirus*)--were determined. Aquatic insects (primarily dipterans, ephemeropterans, and trichopterans), crayfish, and terrestrial organisms (primarily insects)

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composed most of the food eaten. These fish fed primarily during daylight, before daily hydropower generation began, and little or no feeding occurred during generation. Consequently, few organisms entrained from the reservoir or displaced from the tailwater during hydropower generation were eaten by these fish.

Preface

This study is part of the Environmental and Water Quality Operational Studies (EWQOS) Program, Task IIB, Reservoir Releases. The EWQOS Program is sponsored by the Office, Chief of Engineers (OCE), US Army, and is assigned to the US Army Engineer Waterways Experiment Station (WES) under the direction of the Environmental Laboratory (EL). The OCE Technical Monitors were Mr. Earl Eiker, Dr. John Bushman, and Mr. James L. Gottesman.

This report was written by Messrs. D. Hugh Barwick and Patrick L. Hudson of Southeast Reservoir Investigations, National Reservoir Research Program, US Fish and Wildlife Service, Clemson, S. C., under Intra-Army Order No. WESRF 82-268, and Dr. John M. Nestler, EL, WES. The report was edited by Ms. Jessica S. Ruff of the WES Publications and Graphic Arts Division.

Preparation of this report was under the direct supervision of Dr. Nestler and the general supervision of Mr. Mark Dortch, Chief, Water Quality Modeling Group, EL; Mr. Donald L. Robey, Chief, Ecosystem Research and Simulation Division, EL; and Dr. John Harrison, Chief, EL. Dr. Jerome Mahloch was the Program Manager of EWQOS.

During the preparation of this report, COL Tilford C. Creel, CE, and COL Robert C. Lee, CE, were Commanders and Directors of WES and Mr. F. R. Brown was Technical Director. At the time of publication, COL Allen F. Grum, USA, was Director and Dr. Robert W. Whalin was Technical Director.

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Contents

PREY SELECTION AND FEEDING PATTERNS OF FISH IN A SOUTHERN UNITED STATES HYDROPOWER TAILWATER

Introduction

1. Reservoir operation for peaking hydropower operation has well-documented, long-term effects on the downstream, or tailwater, ecosystem (Walburg et al. 1981, 1983). However, the short-term impacts of peaking hydropower operation on specific components of the system, particularly fish, are less well known. Weekday generation may affect fish feeding behavior in the tailwater in several ways. Reservoir biota such as zooplankton, aquatic insects, and fish (particularly larval fish) may be transported into the tailwater (Hudson and Cowell 1966, Benson and Cowell 1968, Walburg 1971, Matter et al. 1983) and eaten by benthos or fish (Walburg 1971). Additionally, the high velocities associated with peaking power generation produce a temporary catastrophic drift response by tailwater invertebrates (Armitage 1977; Brooker and Hemsworth 1978; Matter, Hudson, and Saul 1983). This drift may be similar to drift in unregulated streams during which the entrained organisms are eaten by fish (Minckley 1963; Griffith 1974; Mancini, Busdosh, and Steele 1979). However, the highly fluctuating flows and the altered water quality of the releases may interfere with the feeding behavior of fish. Thus, drifting organisms from both the reservoir and the tailwater may be unavailable to tailwater fish. In light of the above unknowns, the objectives of this study were to determine: (a) the prey selected by the most abundant fish in the tailwater relative to the potential prey available, and (b) the effects of peaking releases on the feeding of fish.

Materials and Methods

2. The tailwater of Lake Hartwell is that reach of the Savannah River between Georgia and South Carolina extending 15-20 km downstream from Hartwell Dam (Figure 1). During generation of peaking hydropower

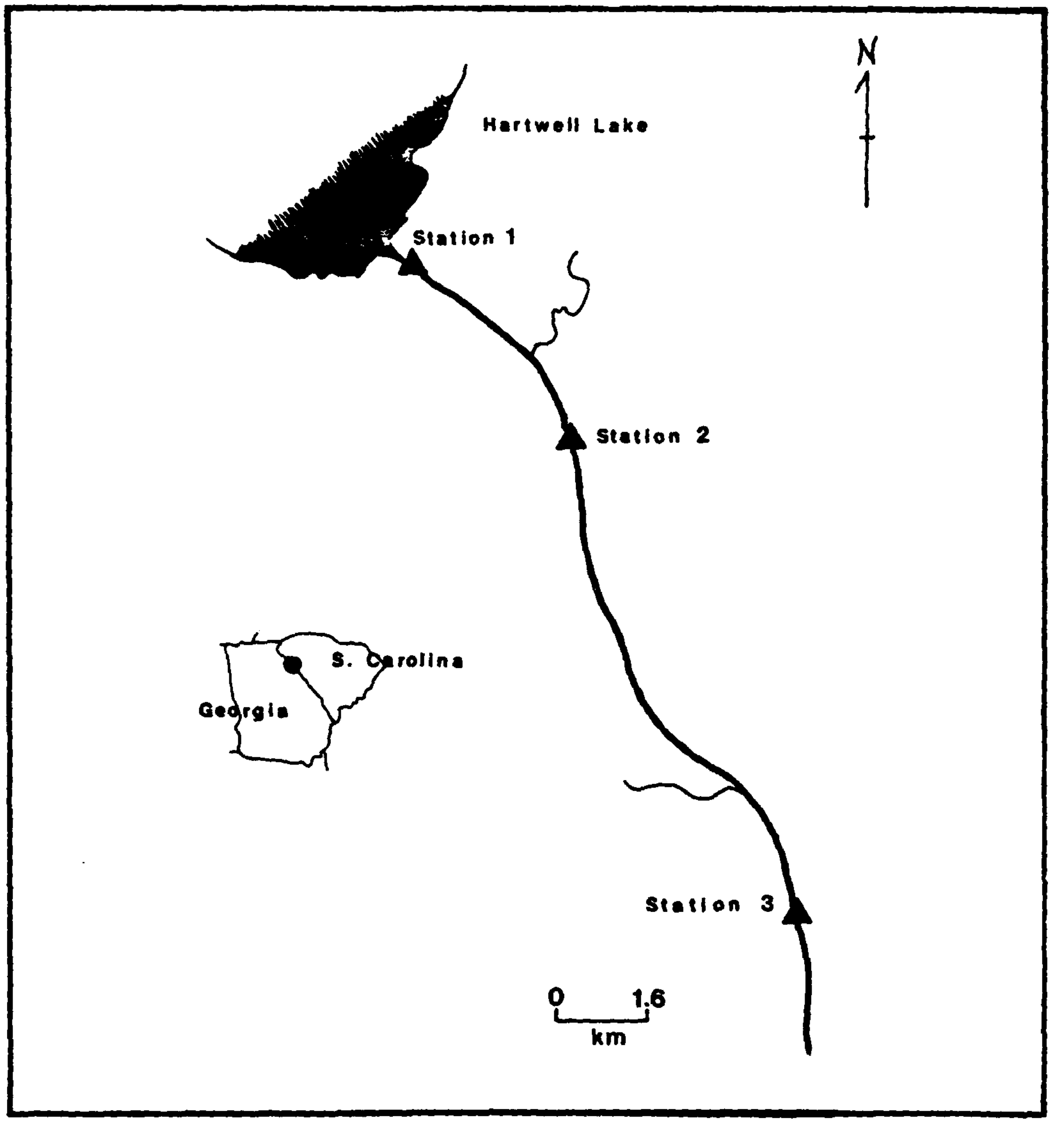

Figure 1. Hartwell Lake and location of tailwater sampling stations

(264 mW) at Hartwell Dam, water is released through 20-m vertical inlets located at a center-line depth of 30 m when Lake Hartwell (22,652 ha) is at full pool (201 m above mean sea level). Flows in the tailwater range from 3 to 11 $m^3 sec^{-1}$ during nongeneration, but may increase to 665 $m^3 sec^{-1}$ during generation. Suckers (***Moxostoma*** spp.) and sunfishes (***Lepomis*** spp.) dominate the tailwater fish population (Barwick and Oliver 1985). A description of Lake Hartwell and additional information

concerning the tailwater and hydropower operations are given by Dudley and Golden (1974); Matter, Hudson, and Saul (1983); Matter et al. (1983); and Barwick and Oliver (1985).

3. Tailwater habitat in the study area (12 km downstream from Hartwell Dam) consists of a river channel that is 180 to 200 m wide and 1.8 to 6.0 m deep during generation. Only 66 percent of this area is inundated during nongeneration, and flowing water (>0.1 m sec^{-1}) is limited to a narrow channel (7-14 m wide and 0.5 to 4.0 m deep) that meanders through the high-flow channel. During nongeneration, this low-flow channel represents 6 percent of the total area inundated by water in the high-flow channel. This study site was selected because it coincided with a station established during long-term monitoring below Lake Hartwell (Walburg et al. 1983). Thus, substantial information was already avail-able for this site. The largest area of water in the tailwater during nongeneration is interspersed throughout bedrock outcrops in isolated pools less than 0.3 m deep. Bedrock comprises nearly 53 percent of the tailwater substrate, and gravel and sand make up most of the rest. Mud on or near the bank constitutes 1 percent of the substrate during nongeneration. Vegetation covers at least 75 percent of the inundated substrate, and filamentous algae and mats of diatoms and blue-green algae cover most of the inundated bedrock. Macrophytes such as ***Podostemum*** spp. and ***Fontinalis*** spp. are common in riffles. Velocities in the low-flow channel generally range from 0.1 to 0.8 m sec^{-1} during nongeneration. However, flows may be near 1.5 m sec^{-1} in the riffles at this time. The maximum measured velocity during generation was about 1.8 m sec^{-1}.

4. Fish were collected in the tailwater to determine prey selection and feeding patterns. Redbreast sunfish, ***L. auritus***, green sunfish, ***L. cyanellus***, and bluegills, ***L. macrochirus***, were collected on 20-21 July 1982, and each of these sunfishes plus silver redhorse, ***M. anisurum***, were collected on 1-2 September 1982 from an area of the Savannah River about 12 km below Hartwell Dam. Fish were collected by electrofishing, using methods described by Barwick and Oliver (1985), either during the day (0900-1530 hr) before flows increased in the river

due to hydropower generation, or at night (2400-0530 hr) after flows subsided (Figure 2). Electroshocking during the high flows associated with peaking hydropower generation is difficult and dangerous and, therefore, was not attempted.

5. To determine prey selection (i.e., what fish are eating in the tailwater), fish were collected both during pregeneration and post-generation. All collected fish were measured (total length in millimetres) and their stomachs excised (stomach and first half of the gut in silver redhorse). Stomach contents were preserved immediately after collection to facilitate identification of prey. Stomach contents were pooled by species and preserved in 10 percent formalin, as described by Borgeson (1963). Weights (in grams) of fish collected in July were estimated from length-weight regressions obtained from data collected from Lake Hartwell Reservoir tailwater in 1979-80 (Barwick and Oliver

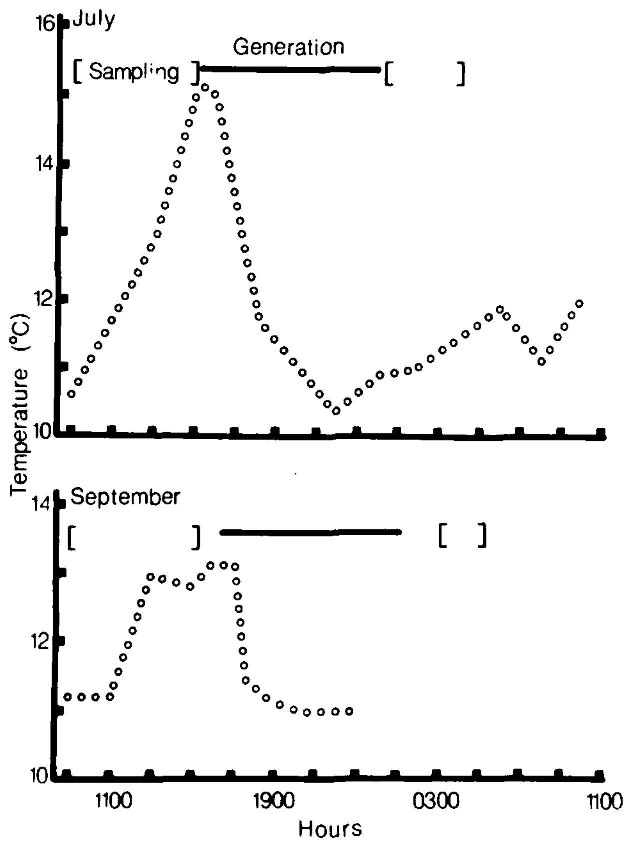

Figure 2. Water temperatures in Hartwell Reservoir tailwater, 20-21 July and 1-2 September 1982

1985); fish collected in September were weighed before their stomachs were removed.

6. To determine feeding patterns (differences in feeding between pregeneration and postgeneration), about 10 additional fish of each species were collected prior to generation and held in a fiberglass fish-transportation tank (232 × 60 × 45 cm) supplied with river water filtered through a 0.75-mm-mesh net, and pumped continuously at a rate of about 10 ℓ min^{-1}. These fish were held until fish were collected after hydropower generation. The stomach contents of fish in the tank and those collected during postgeneration were pooled separately by species. Differences in fish feeding patterns between pregeneration and postgeneration were determined by comparing stomach contents of fish collected during postgeneration with the stomach contents of fish in the holding tank. The fish in the holding tank would not have eaten during generation. Thus, differences in stomach contents between the two groups of fish could only result from feeding during generation by the fish collected in the tailwater during postgeneration.

7. Pooled stomach contents were either examined entirely or subsampled. In subsampling, large, less numerous organisms were removed, and the remaining items were suspended in 400 ml of water and divided with a Folsom Splitter. At least 25 percent of each sample was processed, and the appropriate factor was applied to extrapolate this percentage to total numbers and weights of all items in the stomachs. All organisms were identified to family, unless such identification was prevented by digestion, and some were identified to species. Dry weights (g) were obtained for major groups of organisms by drying them to a constant weight at 60° C. Dry weights of trichopteran larvae and gastropods included the weight of their cases and shells, when present. Feeding periodicity data are presented as dry weight of the stomach contents divided by wet weight of fish in the sample × 10,000 (Keast and Welsh 1968).

8. General trends in abundances of invertebrates in the tailwater during various periods of the hydropower cycle were estimated during daylight hours in September. A high-speed Miller Sampler equipped with

a 0.156-mm-mesh nylon net and a calibrated flowmeter was used. Before generation, one 10-min tow was conducted in the low-flow channel. During generation, the sampler was suspended from a bridge, and 10-min samples were collected during the initial increase in water levels due to generation (surge) and after water levels had been elevated for 2 hr (generation).

9. Basic water quality measurements were made to characterize changes in the tailwater environment associated with hydropower generation. Water temperatures and dissolved oxygen concentrations were measured with a Yellow Springs Instrument Company (YSI) Model 54 temperature-oxygen meter. Measurements were made at 2-hr intervals throughout the study and at 5- to 15-min intervals during the surge. A malfunction of the meter prevented measurements after 2300 hr in September.

Results

Physical and trophic conditions

10. Startup of peaking hydropower generation at Lake Hartwell resulted in rapid and substantial changes in physical conditions in the tailwater. Water levels and current velocities both increased as the surge of water passed the sampling site. Temperature, which had been generally increasing throughout the morning, decreased rapidly as water from the hypolimnion of Lake Hartwell entered the study areas (Figure 2). Dissolved oxygen concentrations were more stable and exceeded 6.0 mg ℓ^{-1} at all times on both sampling dates.

11. Density of invertebrates in the drift in the tailwater was determined in September only, since detailed information on summertime invertebrate distribution, standing crop, and drift was already available for the study site (Matter, Hudson, and Saul 1983; Matter et al. 1983; Walburg et al. 1983). Drift information for the summer and fall time periods indicated that density of both reservoir and tailwater-originated invertebrates in the tailwater was lowest before generation, highest during the surge, and intermediate during continued generation

(Table 1). However, since the surge portion of the generation cycle is relatively short (15-20 min), more invertebrates are transported during the much longer generation period (5-12 hr). During both time periods, the releases associated with power generation transported large numbers of invertebrates from Lake Hartwell and entrained considerable numbers of invertebrates originating from within the tailwater. The smaller mesh size used to obtain the September invertebrate sample is responsible for the increase in numbers observed in Table 1. However, the trends are similar within each time period and, in general, describe the increased availability (concentration) of zooplankton in the tailwater during the surge and generation time periods.

Prey selectivity

12. Prey selection by the four species of fish investigated in this study was determined by pooling the results of the gut analyses over both pregeneration and postgeneration portions of the peaking hydropower generation cycle. The results indicated that all species ate similar foods but in different proportions. Aquatic insects (primarily dipterans, ephemeropterans, and trichopterans), decapods, and terrestrial organisms (primarily insects) composed most of the food (by weight) eaten by all four species (Table 2). Decapods and some miscellaneous aquatic insects were not found in the stomachs of the silver redhorse. Terrestrial organisms were consistently important for all four species, but ephemeropterans were important only for sunfishes.

13. Organisms entrained from Lake Hartwell during hydropower generation were apparently not being extensively eaten by the tailwater fish sampled, since only a few reservoir forms (cladocerans, copepods, and *Chaoborus* spp.) were found in the stomachs (Table 3). Several factors may interfere with feeding by these fish species during generation. The sharply reduced water temperature associated with the passage of hypolimnetic water through the tailwater may cause fish to become temporarily inactive. The density of reservoir organisms in the tailwater may be so low that sight predators such as sunfish cannot forage effectively. The high flows associated with generation may have been too rapid for effective foraging by fish.

14. The silver redhorse may at first be considered an exception because it ate considerable numbers of *Mesocyclops edax* (Table 3), a species of copepod common in reservoirs. However, the form eaten by silver redhorse was smaller than that from the reservoir and the posterior edges of the urosomes were sculptured, in contrast to the smooth edges found in the reservoir form. The *M. edax* eaten by silver redhorse in the Lake Hartwell tailwater may be endemic to the tailwater, along with the cladoceran *Moina brachiata*, which was also frequently eaten. The inferior mouth of silver redhorse, absence of *Moina* from plankton and benthic samples from the lake collected over several years, and presence of the atypical *Mesocyclops* (data collected by Southeast Reservoir Investigations, US Fish and Wildlife Service) suggest benthic feeding in isolated or specialized habitats in the tailwater. Since the *Mesocyclops* and *Moina* were not from the reservoir, the only reservoir-originating invertebrates consumed in significant numbers were *Chaoborus* spp. which were occasionally eaten by green sunfish and bluegills (Table 3).

15. Trichopteran nymphs of the genus *Hydroptila* appeared to be the most important prey for silver redhorse and made up the greatest weight of identifiable prey. Inclusion of the weight of trichopteran cases (which have little or no nutritional value) may have overemphasized the importance of these organisms to the diet of silver redhorse. Terrestrial organisms, *Asellus* spp. and *Hyalella* spp., and dipterans were also relatively important. Dipterans (primarily larvae and pupae of the chironomid genera *Cricotopus* and *Orthocladius*) contributed only 1 percent of the total stomach contents by weight (Table 2), but were more numerous than trichopterans (Table 3). Meyer (1962) also found that silver redhorse from the Des Moines River, Iowa, ate immature chironomids more frequently than they did trichopterans. A disproportionate amount of the large quantity of unidentified material found in this fish species may be dipteran, since their lack of a shell or case may hasten destruction during the mastication and shredding of ingested material by the pharyngeal teeth of this fish.

16. Sunfishes in the Lake Hartwell tailwater had diets similar

to those reported in natural streams (Minckley 1963; Davis 1972; Benke, Gillespie, and Parrish 1979; Coomer, Holder, and Swanson 1979; Mancini, Busdosh, and Steele 1979). All three species had similar relative numbers of ephemeropterans (nymphs and adults of the genera *Ephemerella* and *Pseudocloeon*) and terrestrial organisms in their diet; however, they did vary in the major foods eaten. Dipterans (larvae and pupae of the chironomid genera *Chironomus*, *Cricotopus*, and *Orthocladius*) predominated by weight in redbreast sunfish, decapods in green sunfish, and trichopterans (primarily nymphs of the genus *Hydroptila*) in bluegills (Table 2). Numerically, ephemeropterans were most important in redbreast sunfish and green sunfish, and trichopterans in bluegills (Table 3).

Feeding patterns

17. Changes in feeding patterns of fishes in the tailwater in relation to hydropower generation were apparent. The stomach contents of fishes in the holding tank (representing pregeneration feeding) were generally similar to the stomach contents collected during postgeneration. The relative weights of zooplankton and aquatic insects (the major food items available during generation) in the stomachs did not differ between the two groups of fish (Table 4). Thus, fish feeding during generation was not generally apparent (except for silver redhorse), suggesting that feeding was concentrated during periods of nongeneration.

18. In silver redhorse, terrestrial insects, trichopteran nymphs, and chironomid larvae and pupae were the dominant identifiable prey during both the pregeneration and postgeneration portions of the generation cycle (Table 4). Postgeneration samples contained considerably more aquatic insects and terrestrial organisms than did pregeneration samples (Table 4). The bulk of these organisms were probably eaten from off the bottom since the trichopterans that were found in the fish stomachs form a very small proportion of the macroinvertebrate drift (Matter, Hudson, and Saul 1983).

19. The indication that more aquatic insects and terrestrials were eaten during the postgeneration period may reflect the following

sampling bias. Silver redhorse were the easiest of the fish species to collect in the tailwater. As a consequence, pregeneration samples were collected by 1100 hr, well before the start of generation. Therefore, fish collected during postgeneration would have had more time to feed before generation than the fish collected during the pregeneration period, which would confound the comparison between pregeneration and postgeneration.

20. In redbreast sunfish and green sunfish, weights of decapods were considerably higher in postgeneration than in pregeneration (holding tank) samples collected in September (Table 4). Observations in the tailwater and general observations by Hobbs (1981) indicate that crayfish are secretive during the day and then move from beneath rocks at night. Consequently, they are probably more susceptible to predation by fish at night than during daylight. Active night feeding on crayfish by redbreast sunfish and green sunfish after hydropower generation may explain the increased abundance of crayfish in postgeneration samples in September. It is unlikely these fish actively feed on drifting crayfish during generation since this particular species of crayfish is probably not entrained by the increased flows associated with peaking hydropower generation. Maude and Williams (1983) report that *Cambarus bartoni* (the predominant crayfish in the Lake Hartwell tailwater) has adaptation for life in flowing water; its streamlining prevents it from being swept downstream during generation.

21. Bluegills collected in July contained considerably more terrestrial organisms during postgeneration than during pregeneration (Table 4). During both periods, Coleoptera and Hemiptera (leafhoppers) were numerically dominant forms. Bluegills were collected primarily from backwaters where feeding during generation may have been possible. However, in September, bluegills had similar relative weights of terrestrial organisms during pregeneration and postgeneration periods. Since bluegills were somewhat easier to collect in July than in September, pregeneration fish (fish collected for the holding tank) would have had less time to feed before generation; thus, comparisons between pregeneration and postgeneration may be biased as in the case of silver redhorse.

Discussion

22. The results of this study indicate that peaking hydropower generation causes changes in food selection and feeding patterns of the fish investigated in this study. Predation on drifting organisms during nongeneration appeared to be the major, clear-cut mode of feeding in the Lake Hartwell tailwater even when only small numbers of aquatic insects were drifting before generation in September. Predatory feeding on drift was indicated primarily by the large numbers and life history stage of the chironomids (pupae and adults), ephemeropterans (adults), and trichopterans (pupae and adults) found in all four species of fish (Table 3). Benthic sampling in the Lake Hartwell tailwater (data collected by Southeast Reservoir Investigations, US Fish and Wildlife Service) indicated that pupae of trichopterans and chironomids rarely made up more than 6 percent of the benthic population by numbers at any one time, and adult ephemeropterans were rarely collected. However, tailwater fish (primarily green sunfish and bluegills) ate more adults and pupae than they did immatures of a given group (Table 3). Presence of terrestrial organisms also indicates that during pregeneration a substantial number of insects fall on the water surface where they may be eaten by fish.

23. Although predation on aquatic insects and terrestrial insects on the water surface during pregeneration is the major mode of feeding by fish (other than silver redhorse) in the tailwater, an additional method of feeding by fish that is influenced by peaking hydropower generation was also indicated. After generation, pupae and newly emerged adults of diptera, ephemeroptera, trichoptera, and adult terrestrial insects were concentrated behind obstructions, such as rocks and logs. Ephemeropteran adults were mainly subimagos, indicating that they were not returning to lay eggs, but that they had been trapped in the surface film. These organisms were observed to be preyed on by fish.

24. The following mechanism may explain both the above observation and apparent inconsistencies in the feeding study. During the night and early morning (pregeneration), aquatic insects emerge more or

less randomly on the water surface. During generation these emerging aquatic insects, as well as terrestrial insects that have fallen into the water, concentrate in eddies behind large obstructions in the tailwater. Sunfish were observed feeding on these concentrated organisms during generation the following day. Alternatively, the organisms on the water surface may become waterlogged and sink through the eddie to concentrate on the silt and sand shadow behind the obstruction where they may be eaten by bottom-feeding fish such as silver redhorse.

25. The fate of organisms flushed from the reservoir into the tailwater was not determined in this study. The data confirmed that Matter, Hudson, and Saul (1983) were correct in questioning the ability of fish in the Lake Hartwell tailwater to exploit entrained zooplankton and *Chaoborus* released from the reservoir. This appeared to be true at least for the four species of fish studied during the two time periods. The entrained organisms may be utilized by benthic predators or scavengers in the tailwater or they may be flushed out of the tailwater.

26. Consumption of tailwater biota by fish appears to be related to daily flow regimes associated with peaking hydropower operations. The exposed and slack-water areas of the tailwater during nongeneration apparently attracted molting aquatic insects and terrestrial forms that were subsequently captured by flows during generation. These insects provided tailwater fish with an important source of food that is generally not abundant in unregulated streams. Additionally, the composition of invertebrate taxa found in the tailwater was determined by the presence of the reservoir and the physical and chemical characteristics of the releases (Walburg et al. 1981). Aquatic macroinvertebrates ingested by the four species of fish investigated in this study were predominantly larval stages of periphyton scrapers. Growth of tailwater periphyton is considerably enhanced by the typically clear, nutrient-rich water from the deep-release ports of Lake Hartwell (Walburg et al. 1983; Matter, Hudson, and Saul 1983).

Conclusions

27. The four species of fish studied fed primarily on drifting pupal and adult aquatic insects and terrestrial insects during pregeneration and postgeneration periods.

28. Reservoir invertebrates were not utilized as a major food source by the tailwater fish studied in this investigation.

29. The high flows associated with generation apparently prohibited the fish in this study from feeding on drifting macroinvertebrates. However, these same flows appear to concentrate floating macroinvertebrates behind large obstructions where they may be readily eaten by fish. This process requires further study.

30. The location of the reservoir release ports is important in structuring the benthic invertebrate community. Dominant fish-food organisms were scrapers that probably fed on the abundant periphyton growing in the clear, nutrient-rich flows of the tailwater.

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Table 1

Density of Invertebrates (Numbers per m^3) in the Hartwell Reservoir Tailwater During Various Periods in the Hydropower Generation Cycle

Group	July*			September		
	Pregeneration	Surge	Generation	Pregeneration	Surge	Generation
Reservoir**	16	25	150	1,490	11,280	6,241
Oligochaeta	T†	26	9	--	1,110	60
Diptera	T	20	5	--	970	30
Ephemeroptera	T	5	1	--	60	3
Miscellaneous††	--	3	T	--	200	7

* Data from Matter, Hudson, and Saul (1983)

** Invertebrates primarily of reservoir origin (i.e., mostly zooplankton, but included a few *Chaoborus* spp.).

† T = trace (<0.05).

†† Trichoptera and invertebrates of terrestrial origin.

Table 2

Dry Weights (g) of Organism Groups Eaten by Fish in Hartwell Reservoir Tailwater

(July and September 1982)*

	Fish							
	Silver Redhorse**		Redbreast Sunfish		Green Sunfish		bluegill	
Organisms	(N=30;313-500)	Percent of Total Food	(N=48;81-194)	Percent of Total Food	(N=78;86-184)	Percent of Total Food	(N=61;63-205)	Percent of Total Food
Cladocera and Copepoda†	0.0100	0.1	0.0002	T††	0.0016	T	0.0052	0.1
Asellus spp. and *Hyalella* spp.	0.1208	1.2	0.0400	0.9	0.0957	1.1	0.0936	2.0
Decapoda (crayfish)	--	--	0.2490	5.4	3.5760	41.7	0.0026	0.1
Diptera	0.1088	1.0	1.4072	30.5	0.4496	5.2	0.4019	8.8
Ephemeroptera	0.0536	0.5	1.0757	23.3	1.4798	17.3	0.6600	14.4
Trichoptera	1.1872	11.3	0.2649	5.7	0.5515	6.4	0.9256	20.2
Miscellaneous aquatic insects‡	--	--	0.0107	0.2	0.0468	0.6	0.0159	0.4
Terrestrials‡‡	0.1892	1.8	0.3426	7.4	0.7996	9.3	0.5066	11.0
Periphyton	0.0324	0.3	0.0503	1.1	0.0233	0.3	0.0199	0.4
Miscellaneous§	0.0736	0.7	0.0521	1.1	0.0655	0.8	0.0577	1.3
Unidentified	8.7108	83.1	1.1294	24.4	1.4853	17.3	1.8948	41.3
Total	10.4864		4.6221		8.5747		4.5838	

* Data combined. Numbers in parentheses indicate number of (N=) stomachs examined and range in size (mm) of fish sampled.
** Collected only in September 1982.
† Primarily *Moina brachiata* and *Mesocyclops edax*.
†† T = trace (<0.05 g).
‡ Megaloptera, Odonata, and Plecoptera.
‡‡ Mostly terrestrial insects, but terrestrial earthworms (Oligochaeta), semiterrestrial Lumbriculidae, and Arachnida (spiders) are included.
§ Ostracoda, Hydracarina, and Gastropoda (Physidae).

Table 3

Numbers of Organisms Most Frequently Eaten by Fish in Hartwell Reservoir Tailwater (July and September 1982)

Organisms	Fish: Silver Redhorse*	Redbreast Sunfish	Green Sunfish	Bluegill
Cladocera and Copepoda**	1,652	33	118	369
Asellus spp. and *Hyalella* spp.	1,528	176	528	593
Decopa (crayfish)		2	10	2
Diptera				
Chironomidae				
Larvae	3,612	455	159	367
Pupae	1,556	274	228	279
Adults	264	17	131	167
Simuliidae				
Larvae	48	51	36	145
Pupae	20			
Adults	112			
Tipulidae				
Larvae	44	44	17	22
Pupae		1	1	
Adults		5	11	13
Others†				
Larvae	56	5	4	14
Pupae	152††	1	2	1
Adults	104††	2	167‡	94‡
Ephemeroptera				
Nymphs	532	524	694	721
Adults	56	669	1,387	428
Trichoptera				
Nymphs	1,280	260	590	1,013
Adults	176	26	179	165
Terrestrial forms‡‡	184	93	300	287

* Collected only in September

** Primarily *Moina brachiata* and *Mesocyclops edax*.

† Culicidae, Chaoboridae, Ceratopogonidae, Stratiomyidae, Dolichopodidae, Ephydridae, and unidentified dipterans.

†† Primarily Ceratopogonidae.

‡ Primarily *Chaoborus* spp.

‡‡ Mostly terrestrial insects, but includes terrestrial earthworms (Oligochaeta), semiterrestrial lumbriculidae, and Arachnida (spiders).

Table 4

Relative Weights* of Organism Groups Eaten by Fish** in Lake Hartwell Tailwater During Pregeneration and Postgeneration Periods (July and September 1982)

	Silver Redhorse†		Redbreast Sunfish				Green Sunfish				Bluegill			
	September		July		September		July		September		July		September	
Organisms	Pre-generation (N=10)	Post-generation (N=10	Pre-generation (N=10)	Post-generation (N=10)	Pre-generation (N=6)	Post-generation (N=4)	Pre-generation (N=15)	Post-generation (N=15)	Pre-generation (N=10)	Post-generation (N=10)	Pre-generation (N=10)	Post-generation (N=11)	Pre-generation (N=10)	Post-generation (N=10)
Cladocera and Copepoda	T††	T	T	--	--	--	0.2	T	--	T	T	--	T	T
Asellus spp. and *Hyalella* spp.	T	0.1	0.1	T	0.1	0.1	0.3	0.1	0.1	0.2	0.1	0.1	0.2	0.2
Decapoda	--	--	--	--	--	7.8	21.9	18.8	0.1	2.5	T	--	--	--
Aquatic insects‡	0.1	1.3	13.3	11.6	2.1	4.0	11.0	9.4	3.2	2.5	3.9	4.0	3.4	3.1
Terrestrial forms‡‡	T	0.3	3.1	0.9	0.2	T	5.5	3.9	0.1	0.2	0.2	3.8	0.3	0.4
Periphyton	T	T	--	--	--	0.8	0.3	--	--	--	--	--	--	0.1
Miscellaneous§	T	T	0.4	0.2	T	0.7	0.8	T	T	T	T	0.3	0.1	T
Unidentified	0.9	7.9	4.0	7.2	1.6	1.4	3.8	8.9	1.9	4.7	3.1	6.7	3.1	5.7

* Dry weight of the organisms in grams divided by the net weight of fish in grams × 10,000.
** Number in parentheses (N=) represents number of stomachs sampled.
† Collected only in September.
†† T = trace (<0.05 g).
‡ Diptera, Ephemeroptera, Megaloptera, Odonata, Plecoptera, and Trichoptera.
‡‡ Mostly terrestrial insects, but terrestrial earthworms (Oligochaeta), semiterrestrial Lumbriculidae, and Arachnida (spiders) are included.
§ Ostracoda, Hydracarina, and Gastropoda (Physidae).

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